COOLIDGE X-RAY TUBE

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Instruction Book 89136B

Supersedes 89136A

COOLIDGE X-RAY TUBE

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GENERAL ELECTRIC COMPANY
SCHENECTADY, N. Y., U. S. A.

FEBRUARY, 1920

COOLIDGE X-RAY TUBE

GENERAL DESCRIPTION

The Coolidge X-Ray Tube cosists of a tube exhausted to a pressure of not more than a few hundreds of a micron (a micron is 0.001 mm.) in which is supported a cathode so arranged that it may be heated electrically; an electrically conducting cylinder or ring connected to the heated cathode and so located with reference to it as to focus the cathode rays on a target, and an anti-cathode or target which functions as an anode.

CHARACTERISTICS

The important characteristics of the Coolidge Tube are the following:

1. No discharge current through the tube unless the filament is heated.
2. The amount of discharge current is determined primarily by the amount of current passed through the filament and hence by the temperature produced.
3. The penetrating power of the X-rays is determined by the voltage across the tube terminals.
4. The starting and running voltages are the same.
5. The allowable energy input is determined by the size of the focal spot.
6. Continuous operation is possible without change of characteristics.
7. The focal spot is fixed in position.

TYPES

Coolidge X-ray Tubes are manufactured in three different types:

Universal Type, Coolidge X-Ray Tube.

Radiator Type, Coolidge X-Ray Tube.

Radiator Dental Type, Coolidge X-Ray Tube.

UNIVERSAL TYPE COOLIDGE X-RAY TUBE

DESCRIPTION OF UNIVERSAL TYPE

DIMENSIONS

The bulb of the universal type tube is 7 in. in diameter. The over-all length is approximately 20 in.

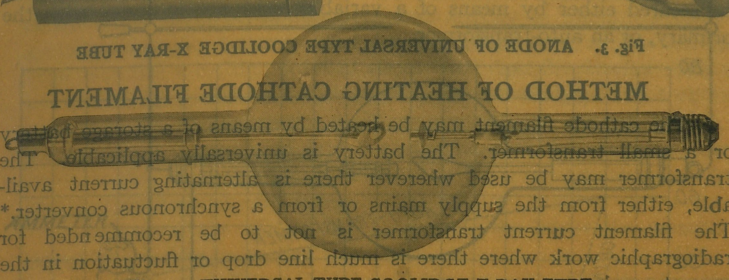

Fig. 1. UNIVERSAL TYPE COOLIDGE X-RAY TUBE

THE CATHODE

The filament (A), Fig 2, which forms the cathode, consists of a closely wound spiral of tungsten wire.

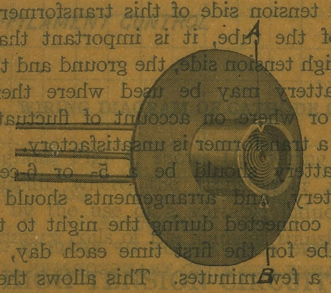

Fig. 2. CATHODE OF UNIVERSAL TYPE COOLIDGE X-RAY TUBE

FOCUSING DEVICE

This consists of a cylindrical tube of molybdenum (B), Fig. 2, with a flange, mounted concentric with the tungsten filament and with its inner end projecting about 0.5 mm. beyond the plane of the latter. Besides acting as a focusing device it also prevents any electron discharge from the back of the cathode.

ANTI-CATHODE OR TARGET

The anti-cathode or target, Fig. 3, which also serves as anode, consists of a single piece of wrought tungsten (C) attached to a molybdenum rod (D) and supported by a split iron tube (E).

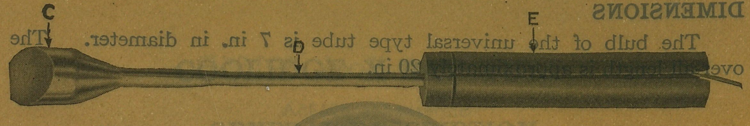

Fig. 3. ANODE OF UNIVERSAL TYPE COOLIDGE X-RAY TUBE

METHOD OF HEATING CATHODE FILAMENT

The cathode filament may be heated by means of a storage battery or a small transformer. The battery is universally applicable. The transformer may be used wherever there is alternating current available, either from the supply mains or from a synchronous converter.* The filament current transformer is not to be recommended for radiographic work where there is much line drop or fluctuation in the current supply.

The transformer is generally used wherever alternating current is available. This transformer should have a low tension output of 10 to 12 volts and not over 5 amperes. It should be capable of finely graduated control by means of either a resistance or variable inductance device. As the low tension side of this transformer will be brought to the full potential of the tube, it is important that it be thoroughly insulated from the high tension side, the ground and the patient.

The storage battery may be used where there is no source of alternating current or where on account of fluctuation of voltage and line drop, the use of a transformer is unsatisfactory.

The storage battery should be a 5- or 6-cell (10- or 12-volt) 40-ampere-hour battery, and arrangements should be made so that the battery may be connected during the night to the charging circuit. Before using the tube for the first time each day, the filament circuit should be closed for a few minutes. This allows the battery to reach a stable condition and so eliminates fluctuations in the filament current. (A fully charged storage battery shows 2.5 volts per cell, dropping rapidly to a stable point of 2 volts.) It is inadvisable to charge the battery at frequent intervals during the day owing to the trouble from instability in voltage referred to above.

If battery leads other than those furnished with the tube are used they should not be of greater resistance than these. Leads of too great length will add enough resistance to the filament circuit so that additional cells of battery may be needed. This may be corrected by the use of heavier wire.

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* The term synchronous converter is used to designate what is sometimes known as "a rotary" or "a rotary converter."

Whether the battery or transformer is used for heating the filament the best technique demands the use of an ammeter in the filament circuit. The meter should have a 5-ampere scale large enough to be easily read to the nearest hundredth of an ampere.

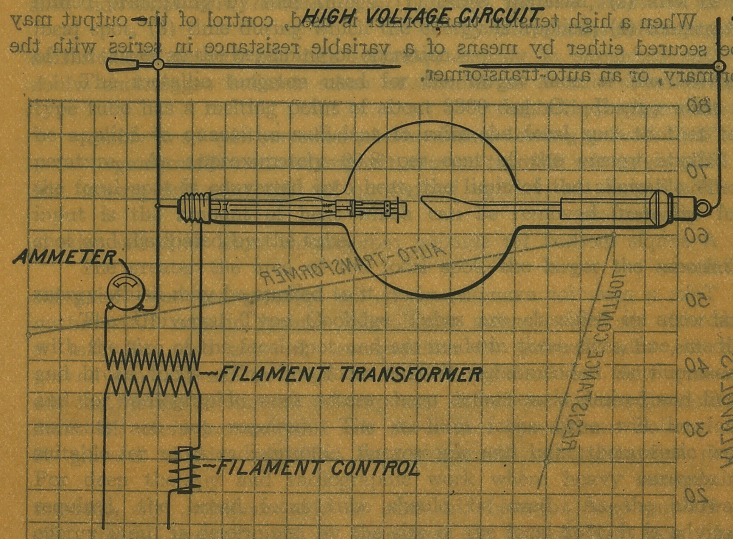

Fig. 4. WIRING DIAGRAM OF CATHODE CIRCUIT

The above diagram, Fig. 4, shows the wiring and control of the filament heating circuit where the transformer is used and where control is obtained by the use of a variable inductance device placed in series with the primary coils of the filament transformer.

HIGH TENSION CIRCUIT

SOURCES OF CURRENT SUPPLY

The Universal Coolidge Tube may be operated in connection with the following devices for the production of high tension electricity, the static machine, induction coil or high tension transformer.

RECTIFICATION OF CURRENT

This tube will successfully rectify its own current provided the energy input is not such as to heat the focal spot or any part of the focal spot to a temperature approximating that of the cathode filament. In practice, however, it has been found impossible to restrict the use of the tube to comply with the above condition. *For this reason, we recommend the use of this tube only with rectified current.*

The tube should never be operated in connection with a transformer or an induction coil, without the interposition of a suitable valve tube or mechanical rectifier.

CONTROL OF CURRENT

When a high tension transformer is used, control of the output may be secured either by means of a variable resistance in series with the primary, or an auto-transformer.

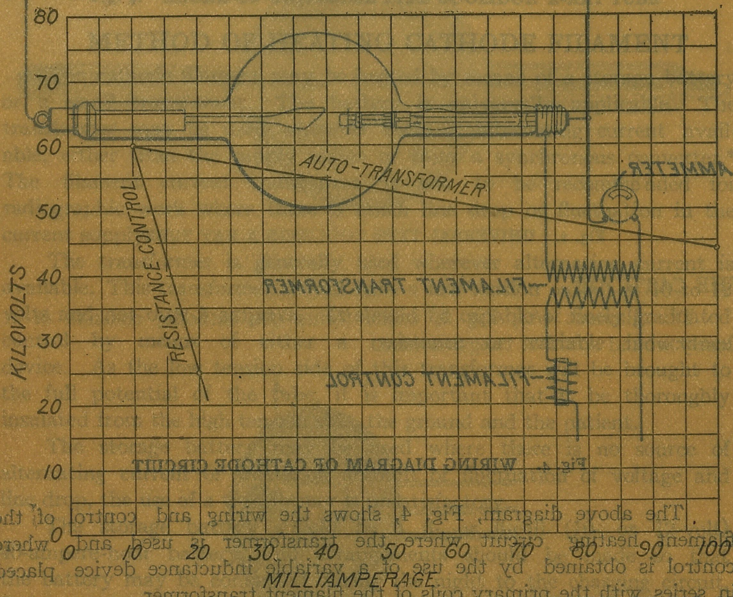

Fig. 5. CURVE SHOWING COMPARISON OF RESULTS OBTAINED BY USE OF RESISTANCE AND AUTO-TRANSFORMER CONTROLS

In diagnostic work, it has been found that it is almost impossible to obtain duplication of results when a series resistance control is employed for this purpose. We recommend that an auto-transformer be used for control for all diagnostic work and resistance control for therapeutic work.

With either method of control it is advisable to have a quick acting circuit breaker in the primary side of the high tension transformer to immediately open the circuit in case of any accidental ground in the high tension circuit.

Reference to the curves shown in Fig. 5, will show the results secured by the use of a resistance control, as compared with the use of an auto-transformer.

CAPACITY OF THE TUBE

Capacity refers to the amount of energy that a tube will carry. Energy may be considered as the product of the voltage (spark gap) multiplied by the milliamperage. The allowable energy input is determined principally by four things, (1) target material, (2) area of the focal spot, (3) time during which the energy is applied, (4) temperature of the target at the beginning of operation.

The metallic tungsten used for the target face of the universal type tube has a melting point of about 3300 deg. C. Energy must not be applied in quantities sufficient to raise the focal spot to that temperature. As approximately 99.8 per cent of the energy applied to the focal spot is converted into heat, the limit of the allowable energy input is the amount of heat which can be removed from the focal spot and dissipated by the tube.

The greater the area of the focal spot, the larger the amount of energy which may be applied to it.

The Universal Type Coolidge Tubes are classified in accordance with the size of the focal spot and are made in three sizes, fine, medium and broad focus. The fine focus tube is recommended for fluoroscopy and for radiographic work where sharp definition is desired and heavy currents are not required. The medium focus tube will be found suitable for most radiographic, fluoroscopic and light therapeutic work. For deep therapy and radiographic work where heavy currents are required, the broad focus tube should be used. As the allowable energy input is determined by the size of the focal spot, it is advisable always to keep the amount of current used within the following limits, as by so doing the operator is in general assured of satisfactory operation and long tube life. Based on the voltage corresponding to a 6-inch spark gap between points, the fine focus tube should not be made to carry more than 25 milliamperes of current, the medium focus 50 milliamperes and the broad focus 80 milliamperes. If possible, it is always advisable to start exposures with the target cold, or at a temperature below that corresponding to visible redness when the energy input approaches these limits. The tube may be operated at either greater or less voltage, as indicated by the parallel spark gap, but the current should be correspondingly increased or decreased so that the total energy input never exceeds the liminations given above.

The above considerations apply to the tube when used for radiographic work. For continuous operation in radiotherapy, the limiting factor is not so much the target as the glass of the bulb. It is possible to get the body of the target so hot that heat radiated from it may cause gas to be driven out of the glass or may even melt the glass. Adequate cooling of the bulb by forced air circulation is necessary to prevent this.

METHOD OF OPERATION

The filament must always be lighted before high tension current is applied to the tube. This precaution is more for the safeguarding of the patient and the apparatus than for protection of the tube. This applies to tubes, whether operated in connection with induction coils or high-tension transformers.

The technique of various operators and the sources of excitation vary so much that it is difficult to make detailed suggestions which are universally applicable.

The following general considerations, however, may be of value:

The higher the filament current, the greater the milliamperage.

The higher the voltage backed up by the tube the greater the penetration.

A simple method for starting radiographic work with the tube is as follows:

Take a case, for example, where the operator has been doing his work with the high tension transformer control on the 10th button with his tube drawing 30 milliamperes. In this case, all that is necessary with the Coolidge Tube is to light up the filament having the filament control set for the least possible amount of current, set the high tension transformer control on the 10th button, close the main switch and adjust the filament control until the tube is drawing 30 milliamperes.

Having once adjusted the tube to this condition, the operator should read and record the amperage in the filament circuit. To reproduce the condition he then needs merely to adjust the filament current to this same value and set his high tension transformer control on the same button. In this way, after his technique is once established, he never tests the tube by operating it, but is guided solely by the ammeter and the high tension transformer control button. While this method is generally applicable, it is not universally so, as it will be found that with certain types of generators the same control button and the same milliamperage as has been used with other tubes will not give the same penetration.

In other cases, the radiographer will be accustomed to adjust his tube by means of the milliammeter and the parallel gap. This procedure can be applied equally as well to the Coolidge Tube, and will naturally be the one first used in all cases where the operator is not familiar with his machine. Knowing that he wants, for example, 20 milliamperes and a 5-in. parallel gap, he will start with the filament control adjusted for the lowest possible current. He will then adjust the filament control and run up to higher buttons on the main control until the tube is drawing 20 milliamperes and backing up the 5-inch gap. As before he will then read and record the amperage in the filament circuit and the number of the control button and will be subsequently guided solely by this.

When excessively high energy inputs are employed, the tungsten at the focal spot melts and volatilizes. This results in a sudden lowering of the tube resistance which disappears instantly upon lowering the energy input, but the vaporized tungsten deposits in a thin film over the active hemisphere of the tube. (This mirror-like metal deposit on the inside of the glass should not be confused with the violet coloration which always results when the particular kind of glass used in these bulbs is

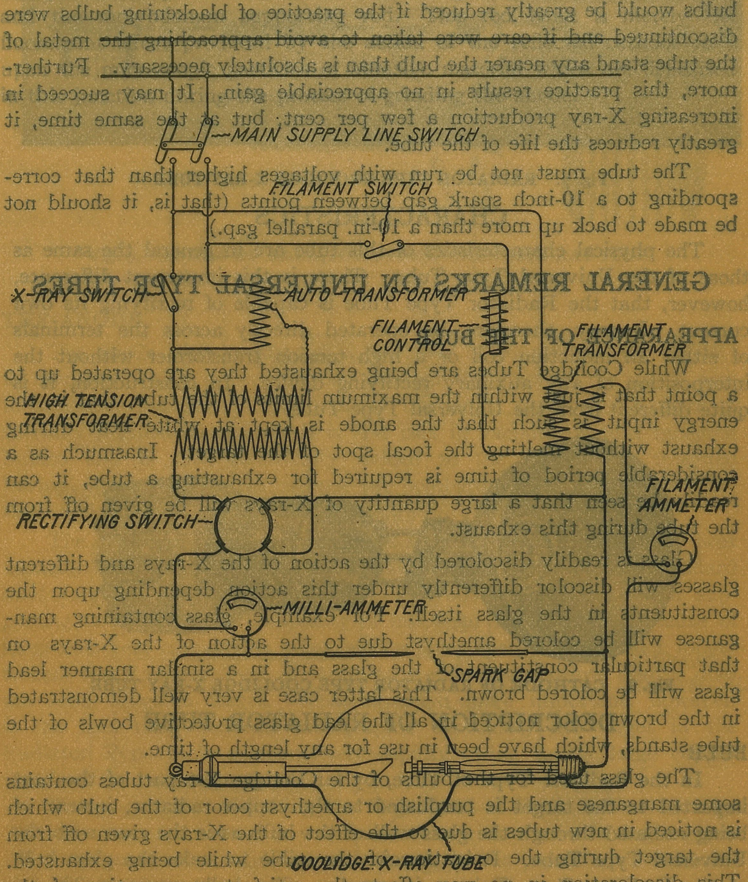

Fig. 6. **WIRING DIAGRAM OF UNIVERSAL TYPE COOLIDGE X-RAY TUBE ON RECTIFIED CURRENT**

subjected to prolonged exposure to X-rays. This violet color is due to some change taking place within the glass itself and is perfectly harmless.) The thin film of tungsten exerts no appreciable filtering effect upon the X-rays, but it does disturb the electrical conditions within the tube. Experiments have shown that a grounded metal wire may be brought up into actual contact with a clean bulb when the tube is operating, whereas with a tube having a metal deposit inside, such a wire must be moved away a number of inches to avoid puncturing the tube. The metal of the tube stand is usually grounded and the number of punctured bulbs would be greatly reduced if the practice of blackening bulbs were discontinued and if care were taken to avoid approaching the metal of the tube stand any nearer the bulb than is absolutely necessary. Furthermore, this practice results in no appreciable gain. It may succeed in increasing X-ray production a few per cent, but at the same time, it greatly reduces the life of the tube.

The tube must not be run with voltages higher than that corresponding to a 10-inch spark gap between points (that is, it should not be made to back up more than a 10-in. parallel gap.)

GENERAL REMARKS ON UNIVERSAL TYPE TUBES

APPEARANCE OF THE BULB

While Coolidge Tubes are being exhausted they are operated up to a point that is just within the maximum limits of the tube, that is, the energy input is such that the anode is kept at white heat during exhaust without melting the focal spot of the target. Inasmuch as a considerable period of time is required for exhausting a tube, it can readily be seen that a large quantity of X-rays will be given off from the tube during this exhaust.

Glass is readily discolored by the action of the X-rays and different glasses will discolor differently under this action depending upon the constituents in the glass itself. For example, glass containing manganese will be colored amethyst due to the action of the X-rays on that particular constituent of the glass and in a similar manner lead glass will be colored brown. This latter case is very well demonstrated in the brown color noticed in all the lead glass protective bowls of the tube stands, which have been in use for any length of time.

The glass used for the bulbs of the Coolidge X-ray tubes contains some manganese and the purplish or amethyst color of the bulb which is noticed in new tubes is due to the effect of the X-rays given off from the target during the operation of the tube while being exhausted. This discoloration in no way affects the satisfactory operation of the tube.

APPEARANCE OF THE TARGET

There is generally a frosted area in the center of the target face of a new tube. This is due to a crystallization of the tungsten during the exhaust of the tube and the size of this area is not an indication of the size of the focal spot.

FLUORESCENT PHENOMENON

During the operation of some universal type tubes there will be noticed a clearly defined red band at the junction of the anode head and the molybdenum supporting rod. This red band is merely the fluorescent effect produced by the action of the reflected cathode rays upon the microscopic particles of abrasive material which are deposited in this junction during the process of grinding the anode.

RADIATOR TYPE COOLIDGE X-RAY TUBE

The radiator tube is designed solely for diagnostic purposes and is recommended for fluoroscopy and radiography only. It should never be used for therapy.

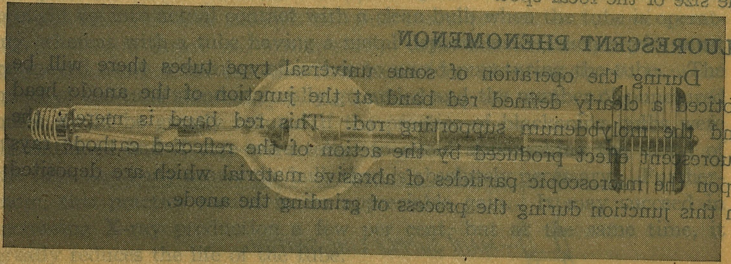

Fig. 7. RADIATOR TYPE COOLIDGE X-RAY TUBE

CHARACTERISTICS

The physical characteristics of this tube are in general the same as those of the Universal Type Tube. There is this important difference, however, that the Radiator Type Tube is capable of rectifying its own current. It may, therefore, be operated directly across the terminals of either an induction coil or a high tension transformer without the interposition of any auxiliary rectifying device. In construction, it is quite different from the Universal Type Tube.

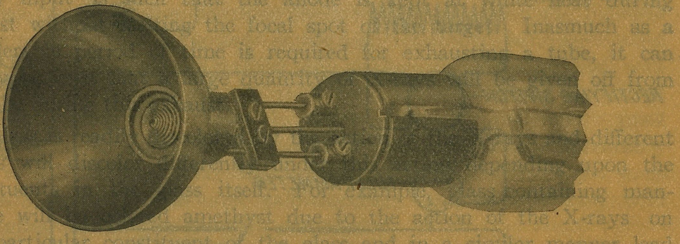

Fig. 8. CATHODE OF RADIATOR TYPE COOLIDGE X-RAY TUBE

DESCRIPTION OF RADIATOR TUBE

BULB

In the Radiator Type of Tube, by far the greatest part of the heat imparted to the target is conducted to the copper radiator, instead of being radiated through the glass wall of the bulb as is the case with the Universal Type Tube. It is, therefore, possible to make the glass bulb of the Radiator Type Tube quite small. The bulb measures 3¾ in. in diameter and the over-all length of the tube is approximately 19 in.

CATHODE

The filament, Fig. 8, which forms the cathode of this tube, is similar to that of the Universal Type Tube.

FOCUSING DEVICE

This consists of a cylindrical tube of molybdenum to which is attached a hemispherical cup of the same metal. By means of this construction a small focal spot with a very uniform distribution of energy is secured.

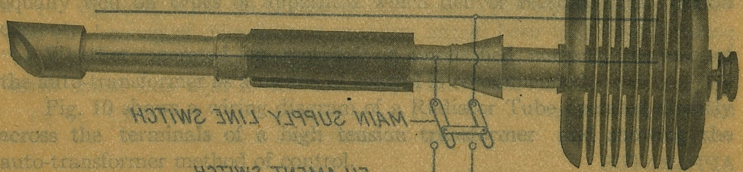

Fig. 9. ANODE OF RADIATOR TYPE COOLIDGE X-RAY TUBE

THE ANODE

The anode stem consists of a solid bar of copper 1.6 cm. (⅝ in.) in diameter which is brought out through the glass of the anode arm to a copper radiator. The head of the anode consists of a mass of specially purified copper which is first cast in vacuum on to a tungsten button and is then electrically welded to the stem. The tungsten button, which receives the cathode ray bombardment is 2.5 mm. (0.1 in.) thick and 9.5 mm. (⅜ in.) in diameter.

The complete target with radiator weighs 860 gm. and has a heat capacity of 81 calories per degree Centigrade, while the present standard solid tungsten target, complete with molybdenum stem and iron supporting tube, has a heat capacity of less than 10 calories. Because of its greater heat capacity, it takes, with a given energy input, much longer to heat the Radiator Type of target to a given temperature than it does the solid tungsten target. What is much more important, however, is the fact that, between radiographic exposures, the target in the Radiator Type cools comparatively rapidly owing to the large copper stem and the radiator.

The importance of having the target cold at the start is shown by the following experiment: It was found that with a tube having a given size focal spot and a solid tungsten target, it was possible, when beginning with the target at room temperature, to run about four times as long with the maximum, allowable energy input, before damaging the tube as a result of "inverse" current, as it was when the experiment was started with the target at a dull red heat.

METHOD OF HEATING THE CATHODE

The filament of this tube is heated in the same manner as that of the Universal Type Tube.

THEORY OF OPERATION

In the Radiator Type of tube, the passage of "inverse" current is avoided by a construction which removes heat from the focal spot so rapidly that, in normal use, it never reaches the temperature at which an appreciable thermionic emission of electrons can take place.

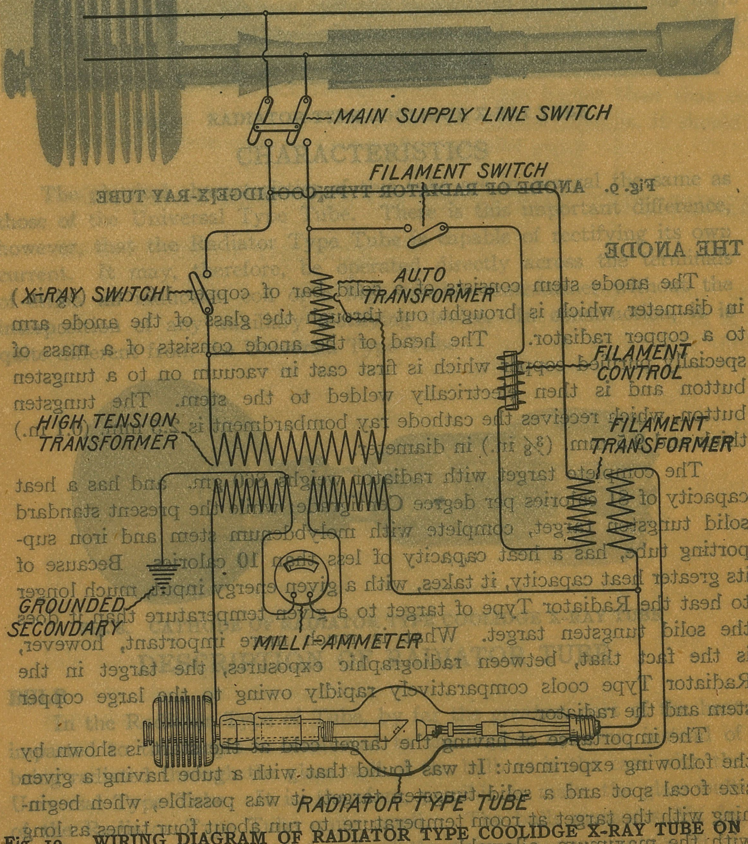

Fig. 10. WIRING DIAGRAM OF RADIATOR TYPE COOLIDGE X-RAY TUBE ON UNRECTIFIED CURRENT

In addition, in this type of tube, the temperature of the focal spot may be raised to that of the cathode spiral and even brought to the fusing point, while the tube is operating on alternating current, without the tube allowing any appreciable "inverse" current to pass. This last fact is probably explained by the presence of gas in the copper-tungsten anode and to the effect of this gas in reducing the thermionic emission of electrons from the focal spot.

HIGH TENSION CIRCUIT

Although this tube is self-rectifying and may be operated directly across the terminals of a high tension transformer or induction coil without the interposition of auxiliary rectifying devices, it will operate equally well on types of apparatus which deliver rectified high tension current.

Whether operated on rectified or unrectified current, the use of the auto-transformer as a means of control is recommended.

Fig. 10 shows a wiring diagram of a Radiator Tube operated directly across the terminals of a high tension transformer and showing the auto-transformer method of control.

CAPACITY OF THE TUBE

The important limiting factor of allowable energy input for the Radiator Tube is the area of the focal spot. On account of the special construction of the anode of the Radiator Type Tube, the heat from the target is rapidly conducted to the outside of the tube and dissipated by the copper radiator. This design insures that operation is always started with a comparatively cool target. The combination of great heat capacity and the ability to quickly conduct and radiate heat from the target makes it possible to apply a greater amount of energy to a given focal area. than with the Universal Type Tube. For a given capacity the focal spot of this type of tube is much smaller than is possible with the Universal Type Tube.

The energy limitation of each Radiator Tube will be found marked on the tube and care should be taken that this limit is not exceeded, otherwise the tube will be damaged.

Where only milliamperage is marked it indicates that the tube may be operated at an energy corresponding to the marked current and the voltage corresponding to a 5-in. parallel spark between points.

Each Radiator Tube is designed to carry the amount of energy indicated by the markings, for a period of time sufficient for making diagnostic radiographs which require the longest exposure or to carry a fluoroscopic load of 5 milliamperes, at a voltage corresponding to a 5-in. spark gap.

The tube should never be operated in such a manner as to heat the body of the anode beyond a temperature corresponding to a dull red heat.

METHOD OF OPERATION

When operating the Radiator Tube on machines delivering rectified current, the same general instructions apply as for the Universal Type Tube, taking care, however, that the energy limitation of the tube is never exceeded.

When operating this tube rectifying its own current, the change of conditions makes necessary certain changes in methods of operation.

THE SPARK GAP

Upon operating the tube directly from the secondary of a transformer, the "inverse" voltage is always higher than the "useful" voltage. Consequently, the measurement of tube voltage by a parallel spark gap used in the ordinary way, would, in general, be very misleading, as the observed spark length corresponds to the "inverse" voltage and not to that which produces the X-rays and hence determines their nature.

APPARATUS

Apparatus for operating this tube rectifying its own current is usually designed to furnish a voltage corresponding to a 5-in. gap between points. Experience has shown that if all radiographs are taken with the same voltage, the *average* quality and diagnostic value is better than if an attempt is made to vary the voltage.

The same has been shown to be true for variations of current through the tube. We, therefore, recommend that the Radiator Tube be operated always with the same voltage (back-up spark) and milliamperage. This should be the maximum capacity for which the tube is designed as indicated by the markings.

When operating a tube in this manner, it is also convenient to use always the same distance between focal spot and plate for most radiographs. This reduces the number of variable factors which influence the making of a radiograph to one, namely, the time of exposure. The operator having a machine and the tube once set to work at a fixed rate of, say, 5-in. back up and 10 milliamperes and a fixed focal-spot distance of 18 in., has his mind entirely free to devote to proper posing of the part to be radiographed. Once posed, he has only to decide the time of exposure necessary and close the switch for that length of time. For example, with the settings made as above, if the part to be radiographed is a hand or wrist, the operator has only to close the switch for 1 sec. For a medium sized knee, 5 sec., for a shoulder 10 sec. If the shoulder is thicker than medium size, 12 sec., or even 14 sec. might be necessary, and if thinner than medium size, 8 sec. will perhaps be sufficient.

The matter of the thickness of the part and the time of exposure may best be determined by the judgment and experience of the operator. The figures given above are intended only as an illustration of the method and not as a guide for the making of radiographs.

Fig. 11 shows the radiator tube enclosed in the lead glass protective shield.

This shield is made of glass containing enough lead so that, for the same protective effect, it is but four times as thick as sheet lead. The walls of this shield are ¼ in. thick, giving X-ray protection equivalent to metallic lead $\frac{1}{16}$ in. thick.

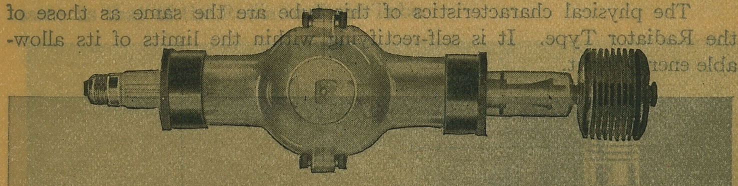

Fig. 11. RADIATOR TYPE COOLIDGE X-RAY TUBE ENCLOSED IN LEAD GLASS PROTECTIVE SHIELD

This shield is made in two halves which are identical and interchangeable. The joint is ground and is made at right angles to the long axis of the shield. It is evident that even if the joint does not fit tightly, no X-rays can escape unless the focal spot happens to be centered directly in line with the ground surfaces.

The outer ends of each half of the shield are threaded to take the screw caps. These caps force tapered split bushings of cork in between the arms of the X-ray tube and the shield. This holds the tube securely in position in the shield and prevents rotation.

The use of this shield is recommended in cases where adequate X-ray protection is not otherwise afforded.

RADIATOR DENTAL TYPE COOLIDGE X-RAY TUBE

The Radiator Dental Type Coolidge X-Ray Tube is designed for dental work and is furnished for use only on types of apparatus which are specially designed for operating this tube. It is intended for making radiographs of the teeth and jaw, only, and is not intended to be used for general radiographic work.

CHARACTERISTICS

The physical characteristics of this tube are the same as those of the Radiator Type. It is self-rectifying within the limits of its allowable energy input.

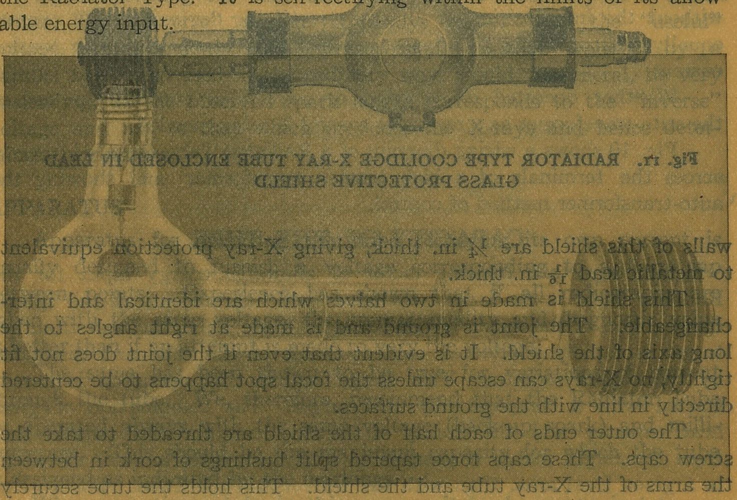

Fig. 12. RADIATOR DENTAL TYPE COOLIDGE X-RAY TUBE

DESCRIPTION OF RADIATOR DENTAL TUBE

This tube is similar to the Radiator Type tube except for a few important differences of form and construction which have been adopted for the purpose of especially adapting this tube to the work which it is expected to perform.

The cathode, focusing device and anode of this tube are the same as are used in the Radiator Tube.

The bulb of this tube measures 3¾ in. in diameter, the cathode arm extends 2 in. from the bulb at a right angle to the anode arm which measures 9 in. from the bulb to the end of the radiator. The advantages of this type of construction are: rays are emitted from the tube in a line with the axis of the anode thereby making it easy to manipulate the tube to the best advantage; the cathode circuit is grounded so that there is only one high tension wire and that is always connected to that part of the tube which is farthest from the subject to be radiographed. This form of construction makes it possible to reduce the film to focal-spot distance to a minimum.

The short film to focal-spot distance makes it possible to obtain satisfactory radiographs of the teeth and jaws with comparatively short exposures.

THEORY OF OPERATION

The theory of operation of the Radiator Dental Type Tube is the same as that of the Radiator Type Tube.

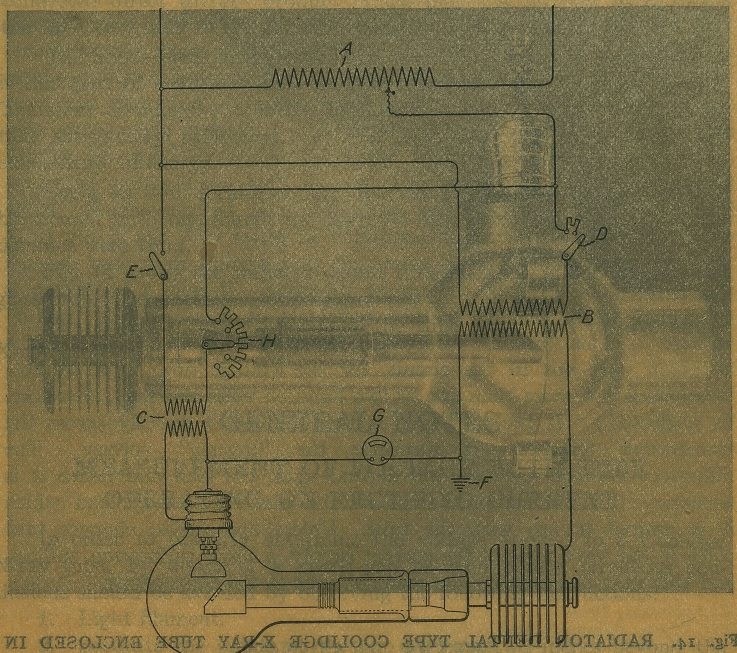

Fig. 13. WIRING DIAGRAM OF RADIATOR DENTAL TYPE COOLIDGE X-RAY TUBE CIRCUIT

COOLIDGE DENTAL X-RAY TUBE WIRING DIAGRAM

A	Auto-transformer—100/120 volts
B	X-ray transformer
C	Filament transformer
D	X-ray switch with resistance
E	Filament switch
F	Ground connection
G	Milliammeter
H	Filament control

HIGH TENSION CIRCUIT

The Radiator Dental Tube is intended to be operated only on machines specially designed for dental work in connection with this particular type of tube.

Fig. 13 shows the wiring diagram of such a machine and the wiring scheme indicated in this diagram is generally followed out by manufacturers of all such machines.

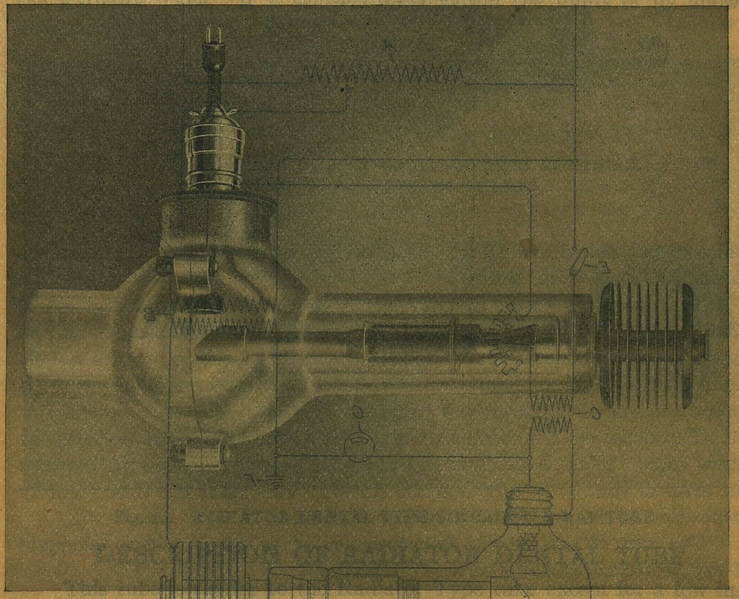

Fig. 14. RADIATOR DENTAL TYPE COOLIDGE X-RAY TUBE ENCLOSED IN LEAD GLASS PROTECTIVE SHIELD

CAPACITY OF THE RADIATOR DENTAL TYPE TUBE

The Radiator Dental Tube is designed to be operated at all times with an energy input not exceeding that corresponding to a current of 10 milliamperes at a "useful" voltage corresponding to a 3-in. parallel spark gap between points.

METHOD OF OPERATION

As this tube is designed to operate only in connection with special machines, and always at a fixed voltage and current, operation is limited to closing the switch for a length of time necessary to produce on the photographic film the effect desired by the operator.

The factor of time is the only variable in the making of radiographs with this tube and this factor will be adjusted in accordance with the judgment and experience of the operator.

It will be noted that the cathode terminal of the dental tube is connected direct to the "ground" which makes it possible to approach the tube very near to the patient without danger of shock.

The anode end, during operation, is at the maximum potential and is that part of the tube which is always farthest away from the patient. The short distance between the focal spot and film makes it possible to take satisfactory radiographs of the teeth and jaws with very little expenditure of energy.

Using an 8-in. focal-spot film distance the photographic effect may be secured with one fourth the energy which would be necessary if the distance were 16 in.

Fig. 14 shows the radiator dental tube enclosed in the special lead glass protective shield.

This shield is designed to hold the tube firmly and to give ample X-ray protection.

GENERAL NOTES

MEASUREMENT OF VOLTAGE WITH TUBE OPERATING ON RECTIFIED CURRENT

In order to properly determine the voltage applied to a Coolidge X-ray tube, by means of a spark gap between points, erroneous conclusions should be avoided by observing the following instructions:

1. Light filament.
2. Separate the points of the gap at least two inches beyond the back-up spark desired.
3. Set the control as near as possible to the point where it will give the desired voltage and current.
4. Close the X-ray switch.
5. Bring the points of the gap together until the spark over occurs.

The distance between the spark points at which the first sparking occurs, indicates the true value of the voltage applied across the terminals of the tube in terms of "parallel spark gap between points." This true value is not obtained if the points of the gap are first set at the desired distance and the X-ray switch afterwards closed. At the instant of closing the switch, a surge in voltage may occur which is much higher than that at which the tube is operating during the exposure.

MEASUREMENT OF VOLTAGE WITH TUBE RECTIFYING ITS OWN CURRENT

Upon operating a tube, which rectifies its own current, directly from the secondary of a transformer, the "inverse" voltage is always higher than the "useful" voltage. Consequently, the measurement of tube voltage by a parallel spark gap, used in the ordinary way, would in general be very misleading. The observed spark length would correspond to the "inverse" voltage and not to that which produces the X-rays and hence determines their nature. A simple and very satisfactory method of dealing with this difficulty consists in connecting an alternating current voltmeter across the primary of the transformer and calibrating once for all this combination of transformer and volt meter. The calibration can be conveniently made with the help of a kenotron connected in series with the X-ray tube. The two tubes should be so connected that current may pass through the X-ray tube only in the proper direction. If now a spark-gap is connected across the X-ray tube terminals, it measures the "useful" voltage. (This "useful" voltage is essentially what it would be if the kenotron were not in the circuit, for the voltage drop in a suitable kenotron is not more than one or two hundred volts and may, therefore, be neglected.) If the spark-gap is then connected directly across the transformer terminals it measures the "inverse" voltage. The difference between the two will depend upon the load and hence it is necessary that the calibration should be made for every load which it is desired to use with the tube. Unless appreciable changes take place in the wave form of the current supply, a single calibration suffices, and this may be made by the manufacturer of the transformer.

METER READINGS

The correct reading of all meters is the point at which the indicating needle comes to rest.

FOCAL SPOT

The size of focal spot is of interest in radiography for the reason that with all other conditions the same, the tube having the smallest focal spot will give the sharpest definition in a radiograph.

The size and form of the focal spot may be determined by making pinhole-camera focal spot pictures of each tube. A convenient method of making this test is as follows:

Take a square sheet of lead, say ⅛ in. thick and of the right size to take the place usually occupied by the diaphragm in the tube stand. Make a conical depression in the center with a machinist's prick-punch, or other suitable tool. With a knife remove the tiny prominence produced in this way on the back of the lead plate, and then, with a pin or small drill, open the hole to the desired size, say 0.02 in. in diameter. (If the hole is too large the focal-spot picture will lack sharpness, and if it is too small, the required time of exposure will be needlessly long.) Put the lead plate and the tube in place in the holder and lay the photographic plate on a table below. The size of the focal-spot-picture may be varied at will by raising or lowering the tube holder. *If it is to be of natural size, the distance from plate to pinhole should be exactly equal to that from pinhole to focal spot.*

It is a good plan to make two exposures, one of which is much longer than the other. The long exposure will then show the full extent of the focal spot, and the shorter one will show the distribution of energy over it.

With a hot cathode tube, the size of focal spot is always the same regardless of the current and voltage employed.

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Instruction Book 89136B

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COOLIDGE X-RAY TUBE

When ordering supplies specify "General Electric"

GENERAL ELECTRIC COMPANY
SCHENECTADY, N. Y., U. S. A.

FEBRUARY, 1920

COOLIDGE X-RAY TUBE

GENERAL DESCRIPTION

The Coolidge X-Ray Tube cosists of a tube exhausted to a pressure of not more than a few hundreds of a micron (a micron is 0.001 mm.) in which is supported a cathode so arranged that it may be heated electrically; an electrically conducting cylinder or ring connected to the heated cathode and so located with reference to it as to focus the cathode rays on a target, and an anti-cathode or target which functions as an anode.

CHARACTERISTICS

The important characteristics of the Coolidge Tube are the following:

1. No discharge current through the tube unless the filament is heated.
2. The amount of discharge current is determined primarily by the amount of current passed through the filament and hence by the temperature produced.
3. The penetrating power of the X-rays is determined by the voltage across the tube terminals.
4. The starting and running voltages are the same.
5. The allowable energy input is determined by the size of the focal spot.
6. Continuous operation is possible without change of characteristics.
7. The focal spot is fixed in position.

TYPES

Coolidge X-ray Tubes are manufactured in three different types:

Universal Type, Coolidge X-Ray Tube.

Radiator Type, Coolidge X-Ray Tube.

Radiator Dental Type, Coolidge X-Ray Tube.

The size and form of the focal spot may be determined by making pinhole-camera focal spot pictures of each tube. A convenient method of making this test is as follows:

Take a square sheet of lead, say ⅛ in. thick and of the right size to take the place usually occupied by the diaphragm in the tube stand. Make a conical depression in the center with a machinist's prick-punch, or other suitable tool. With a knife remove the tiny prominence produced in this way on the back of the lead plate, and then, with a pin or small drill, open the hole to the desired size, say 0.02 in. in diameter. (If the hole is too large the focal-spot picture will lack sharpness, and if it is too small, the required time of exposure will be needlessly long.) Put the lead plate and the tube in place in the holder and lay the photographic plate on a table below. The size of the focal-spot-picture may be varied at will by raising or lowering the tube holder. *If it is to be of natural size, the distance from plate to pinhole should be exactly equal to that from pinhole to focal spot.*

It is a good plan to make two exposures, one of which is much longer than the other. The long exposure will then show the full extent of the focal spot, and the shorter one will show the distribution of energy over it.

With a hot cathode tube, the size of focal spot is always the same regardless of the current and voltage employed.

the desired distance and the X-ray switch afterwards closed. At the instant of closing the switch, a surge in voltage may occur which is much higher than that at which the tube is operating during the exposure.

MEASUREMENT OF VOLTAGE WITH TUBE RECTIFYING ITS OWN CURRENT

Upon operating a tube, which rectifies its own current, directly from the secondary of a transformer, the "inverse" voltage is always higher than the "useful" voltage. Consequently, the measurement of tube voltage by a parallel spark gap, used in the ordinary way, would in general be very misleading. The observed spark length would correspond to the "inverse" voltage and not to that which produces the X-rays and hence determines their nature. A simple and very satisfactory method of dealing with this difficulty consists in connecting an alternating current voltmeter across the primary of the transformer and calibrating once for all this combination of transformer and volt meter. The calibration can be conveniently made with the help of a kenotron connected in series with the X-ray tube. The two tubes should be so connected that current may pass through the X-ray tube only in the proper direction. If now a spark-gap is connected across the X-ray tube terminals, it measures the "useful" voltage. (This "useful" voltage is essentially what it would be if the kenotron were not in the circuit, for the voltage drop in a suitable kenotron is not more than one or two hundred volts and may, therefore, be neglected.) If the spark-gap is then connected directly across the transformer terminals it measures the "inverse" voltage. The difference between the two will depend upon the load and hence it is necessary that the calibration should be made for every load which it is desired to use with the tube. Unless appreciable changes take place in the wave form of the current supply, a single calibration suffices, and this may be made by the manufacturer of the transformer.

METER READINGS

The correct reading of all meters is the point at which the indicating needle comes to rest.

FOCAL SPOT

The size of focal spot is of interest in radiography for the reason that with all other conditions the same, the tube having the smallest focal spot will give the sharpest definition in a radiograph.

UNIVERSAL TYPE COOLIDGE X-RAY TUBE

DESCRIPTION OF UNIVERSAL TYPE

DIMENSIONS

The bulb of the universal type tube is 7 in. in diameter. The over-all length is approximately 20 in.

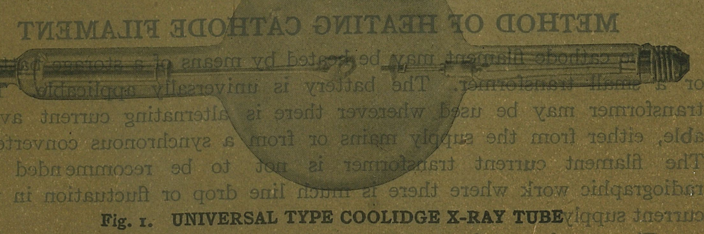

Fig. 1. UNIVERSAL TYPE COOLIDGE X-RAY TUBE

THE CATHODE

The filament (A), Fig 2, which forms the cathode, consists of a closely wound spiral of tungsten wire.

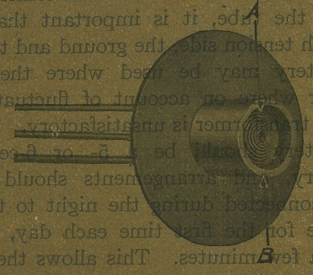

Fig. 2. CATHODE OF UNIVERSAL TYPE COOLIDGE X-RAY TUBE

FOCUSING DEVICE

This consists of a cylindrical tube of molybdenum (B), Fig. 2, with a flange, mounted concentric with the tungsten filament and with its inner end projecting about 0.5 mm. beyond the plane of the latter. Besides acting as a focusing device it also prevents any electron discharge from the back of the cathode.

ANTI-CATHODE OR TARGET

The anti-cathode or target, Fig. 3, which also serves as anode, consists of a single piece of wrought tungsten (C) attached to a molybdenum rod (D) and supported by a split iron tube (E).

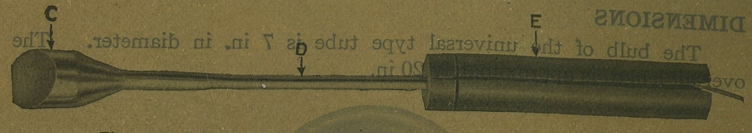

Fig. 3. ANODE OF UNIVERSAL TYPE COOLIDGE X-RAY TUBE

METHOD OF HEATING CATHODE FILAMENT

The cathode filament may be heated by means of a storage battery or a small transformer. The battery is universally applicable. The transformer may be used wherever there is alternating current available, either from the supply mains or from a synchronous converter.* The filament current transformer is not to be recommended for radiographic work where there is much line drop or fluctuation in the current supply.

The transformer is generally used wherever alternating current is available. This transformer should have a low tension output of 10 to 12 volts and not over 5 amperes. It should be capable of finely graduated control by means of either a resistance or variable inductance device. As the low tension side of this transformer will be brought to the full potential of the tube, it is important that it be thoroughly insulated from the high tension side, the ground and the patient.

The storage battery may be used where there is no source of alternating current or where on account of fluctuation of voltage and line drop, the use of a transformer is unsatisfactory.

The storage battery should be a 5- or 6-cell (10- or 12-volt) 40-ampere-hour battery, and arrangements should be made so that the battery may be connected during the night to the charging circuit. Before using the tube for the first time each day, the filament circuit should be closed for a few minutes. This allows the battery to reach a stable condition and so eliminates fluctuations in the filament current. (A fully charged storage battery shows 2.5 volts per cell, dropping rapidly to a stable point of 2 volts.) It is inadvisable to charge the battery at frequent intervals during the day owing to the trouble from instability in voltage referred to above.

If battery leads other than those furnished with the tube are used they should not be of greater resistance than these. Leads of too great length will add enough resistance to the filament circuit so that additional cells of battery may be needed. This may be corrected by the use of heavier wire.

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* The term synchronous converter is used to designate what is sometimes known as "a rotary" or "a rotary converter."

METHOD OF OPERATION

As this tube is designed to operate only in connection with special machines, and always at a fixed voltage and current, operation is limited to closing the switch for a length of time necessary to produce on the photographic film the effect desired by the operator.

The factor of time is the only variable in the making of radiographs with this tube and this factor will be adjusted in accordance with the judgment and experience of the operator.

It will be noted that the cathode terminal of the dental tube is connected direct to the "ground" which makes it possible to approach the tube very near to the patient without danger of shock.

The anode end, during operation, is at the maximum potential and is that part of the tube which is always farthest away from the patient. The short distance between the focal spot and film makes it possible to take satisfactory radiographs of the teeth and jaws with very little expenditure of energy.

Using an 8-in. focal-spot film distance the photographic effect may be secured with one fourth the energy which would be necessary if the distance were 16 in.

Fig. 14 shows the radiator dental tube enclosed in the special lead glass protective shield.

This shield is designed to hold the tube firmly and to give ample X-ray protection.

GENERAL NOTES

MEASUREMENT OF VOLTAGE WITH TUBE OPERATING ON RECTIFIED CURRENT

In order to properly determine the voltage applied to a Coolidge X-ray tube, by means of a spark gap between points, erroneous conclusions should be avoided by observing the following instructions:

1. Light filament.
2. Separate the points of the gap at least two inches beyond the back-up spark desired.
3. Set the control as near as possible to the point where it will give the desired voltage and current.
4. Close the X-ray switch.
5. Bring the points of the gap together until the spark over occurs.

The distance between the spark points at which the first sparking occurs, indicates the true value of the voltage applied across the terminals of the tube in terms of "parallel spark gap between points." This true value is not obtained if the points of the gap are first set at

HIGH TENSION CIRCUIT

The Radiator Dental Tube is intended to be operated only on machines specially designed for dental work in connection with this particular type of tube.

Fig. 13 shows the wiring diagram of such a machine and the wiring scheme indicated in this diagram is generally followed out by manufacturers of all such machines.

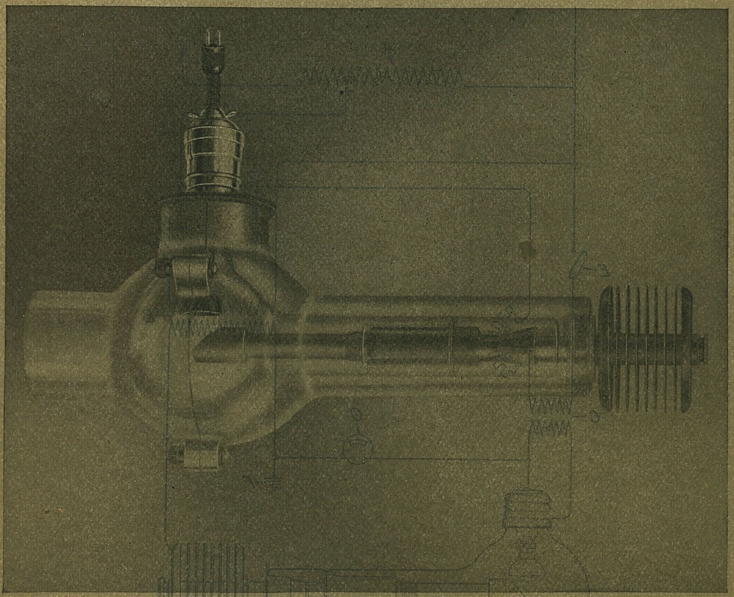

Fig. 14. RADIATOR DENTAL TYPE COOLIDGE X-RAY TUBE ENCLOSED IN LEAD GLASS PROTECTIVE SHIELD

CAPACITY OF THE RADIATOR DENTAL TYPE TUBE

The Radiator Dental Tube is designed to be operated at all times with an energy input not exceeding that corresponding to a current of 10 milliamperes at a "useful" voltage corresponding to a 3-in. parallel spark gap between points.

Whether the battery or transformer is used for heating the filament the best technique demands the use of an ammeter in the filament circuit. The meter should have a 5-ampere scale large enough to be easily read to the nearest hundredth of an ampere.

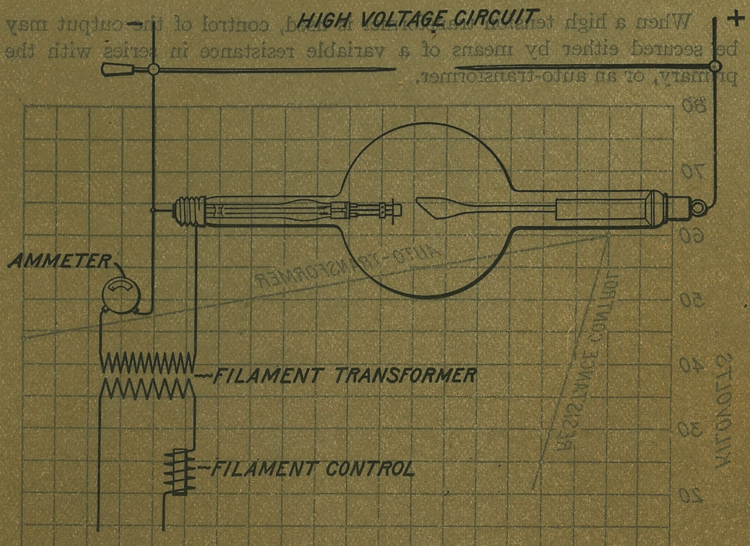

Fig. 4. WIRING DIAGRAM OF CATHODE CIRCUIT

The above diagram, Fig. 4, shows the wiring and control of the filament heating circuit where the transformer is used and where control is obtained by the use of a variable inductance device placed in series with the primary coils of the filament transformer.

HIGH TENSION CIRCUIT

SOURCES OF CURRENT SUPPLY

The Universal Coolidge Tube may be operated in connection with the following devices for the production of high tension electricity, the static machine, induction coil or high tension transformer.

RECTIFICATION OF CURRENT

This tube will successfully rectify its own current provided the energy input is not such as to heat the focal spot or any part of the focal spot to a temperature approximating that of the cathode filament. In practice, however, it has been found impossible to restrict the use of the tube to comply with the above condition. *For this reason, we recommend the use of this tube only with rectified current.*

The tube should never be operated in connection with a transformer or an induction coil, without the interposition of a suitable valve tube or mechanical rectifier.

CONTROL OF CURRENT

When a high tension transformer is used, control of the output may be secured either by means of a variable resistance in series with the primary, or an auto-transformer.

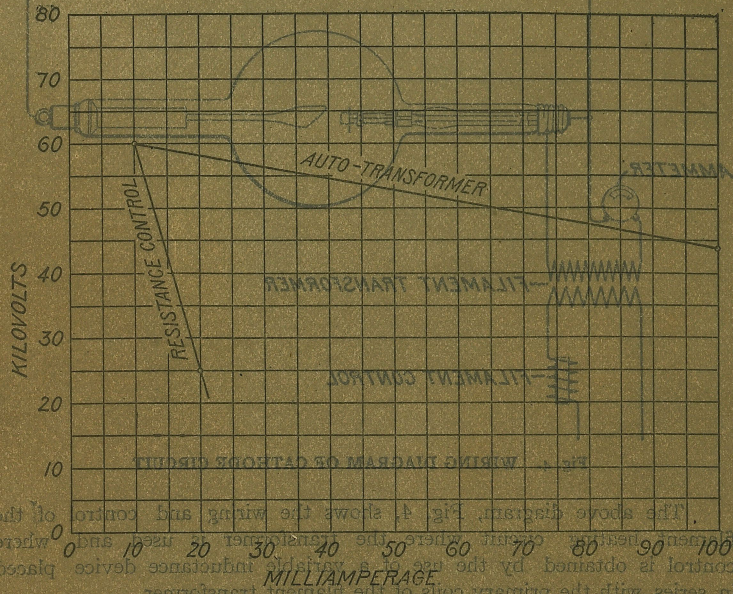

Fig. 5. CURVE SHOWING COMPARISON OF RESULTS OBTAINED BY USE OF RESISTANCE AND AUTO-TRANSFORMER CONTROLS

In diagnostic work, it has been found that it is almost impossible to obtain duplication of results when a series resistance control is employed for this purpose. We recommend that an auto-transformer be used for control for all diagnostic work and resistance control for therapeutic work.

With either method of control it is advisable to have a quick acting circuit breaker in the primary side of the high tension transformer to immediately open the circuit in case of any accidental ground in the high tension circuit.

Reference to the curves shown in Fig. 5, will show the results secured by the use of a resistance control, as compared with the use of an auto-transformer.

the tube which is farthest from the subject to be radiographed. This form of construction makes it possible to reduce the film to focal-spot distance to a minimum.

The short film to focal-spot distance makes it possible to obtain satisfactory radiographs of the teeth and jaws with comparatively short exposures.

THEORY OF OPERATION

The theory of operation of the Radiator Dental Type Tube is the same as that of the Radiator Type Tube.

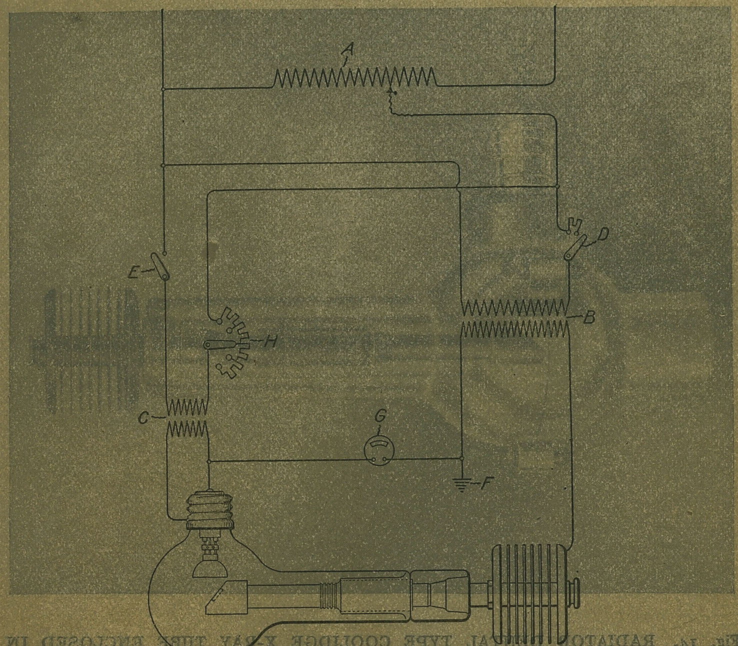

Fig. 13. WIRING DIAGRAM OF RADIATOR DENTAL TYPE COOLIDGE X-RAY TUBE CIRCUIT

COOLIDGE DENTAL X-RAY TUBE WIRING DIAGRAM

A	Auto-transformer—100/120 volts
B	X-ray transformer
C	Filament transformer
D	X-ray switch with resistance
E	Filament switch
F	Ground connection
G	Milliammeter
H	Filament control

RADIATOR DENTAL TYPE COOLIDGE X-RAY TUBE

The Radiator Dental Type Coolidge X-Ray Tube is designed for dental work and is furnished for use only on types of apparatus which are specially designed for operating this tube. It is intended for making radiographs of the teeth and jaw, only, and is not intended to be used for general radiographic work.

CHARACTERISTICS

The physical characteristics of this tube are the same as those of the Radiator Type. It is self-rectifying within the limits of its allowable energy input.

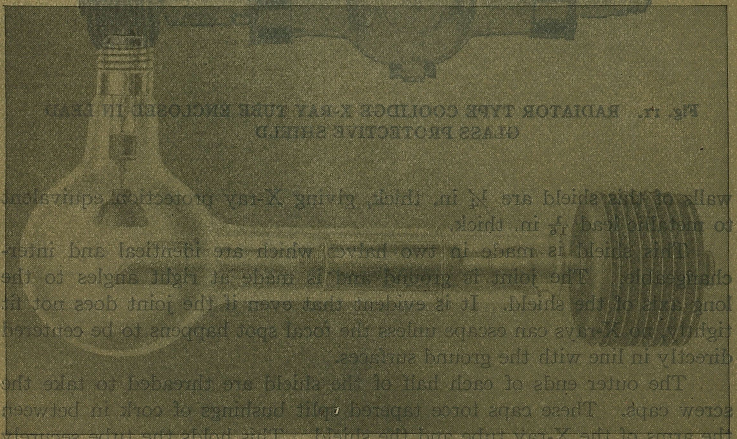

Fig. 12. RADIATOR DENTAL TYPE COOLIDGE X-RAY TUBE

DESCRIPTION OF RADIATOR DENTAL TUBE

This tube is similar to the Radiator Type tube except for a few important differences of form and construction which have been adopted for the purpose of especially adapting this tube to the work which it is expected to perform.

The cathode, focusing device and anode of this tube are the same as are used in the Radiator Tube.

The bulb of this tube measures 3¾ in. in diameter, the cathode arm extends 2 in. from the bulb at a right angle to the anode arm which measures 9 in. from the bulb to the end of the radiator. The advantages of this type of construction are: rays are emitted from the tube in a line with the axis of the anode thereby making it easy to manipulate the tube to the best advantage; the cathode circuit is grounded so that there is only one high tension wire and that is always connected to that part of

CAPACITY OF THE TUBE

Capacity refers to the amount of energy that a tube will carry. Energy may be considered as the product of the voltage (spark gap) multiplied by the milliamperage. The allowable energy input is determined principally by four things, (1) target material, (2) area of the focal spot, (3) time during which the energy is applied, (4) temperature of the target at the beginning of operation.

The metallic tungsten used for the target face of the universal type tube has a melting point of about 3300 deg. C. Energy must not be applied in quantities sufficient to raise the focal spot to that temperature. As approximately 99.8 per cent of the energy applied to the focal spot is converted into heat, the limit of the allowable energy input is the amount of heat which can be removed from the focal spot and dissipated by the tube.

The greater the area of the focal spot, the larger the amount of energy which may be applied to it.

The Universal Type Coolidge Tubes are classified in accordance with the size of the focal spot and are made in three sizes, fine, medium and broad focus. The fine focus tube is recommended for fluoroscopy and for radiographic work where sharp definition is desired and heavy currents are not required. The medium focus tube will be found suitable for most radiographic, fluoroscopic and light therapeutic work. For deep therapy and radiographic work where heavy currents are required, the broad focus tube should be used. As the allowable energy input is determined by the size of the focal spot, it is advisable always to keep the amount of current used within the following limits, as by so doing the operator is in general assured of satisfactory operation and long tube life. Based on the voltage corresponding to a 6-inch spark gap between points, the fine focus tube should not be made to carry more than 25 milliamperes of current, the medium focus 50 milliamperes and the broad focus 80 milliamperes. If possible, it is always advisable to start exposures with the target cold, or at a temperature below that corresponding to visible redness when the energy input approaches these limits. The tube may be operated at either greater or less voltage, as indicated by the parallel spark gap, but the current should be correspondingly increased or decreased so that the total energy input never exceeds the liminations given above.

The above considerations apply to the tube when used for radiographic work. For continuous operation in radiotherapy, the limiting factor is not so much the target as the glass of the bulb. It is possible to get the body of the target so hot that heat radiated from it may cause gas to be driven out of the glass or may even melt the glass. Adequate cooling of the bulb by forced air circulation is necessary to prevent this.

METHOD OF OPERATION

The filament must always be lighted before high tension current is applied to the tube. This precaution is more for the safeguarding of the patient and the apparatus than for protection of the tube. This applies to tubes whether operated in connection with induction coils or high-tension transformers.

The technique of various operators and the sources of excitation vary so much that it is difficult to make detailed suggestions which are universally applicable.

The following general considerations, however, may be of value:

The higher the filament current, the greater the milliamperage.

The higher the voltage backed up by the tube the greater the penetration.

A simple method for starting radiographic work with the tube is as follows:

Take a case, for example, where the operator has been doing his work with the high tension transformer control on the 10th button with his tube drawing 30 milliamperes. In this case, all that is necessary with the Coolidge Tube is to light up the filament having the filament control set for the least possible amount of current, set the high tension transformer control on the 10th button, close the main switch and adjust the filament control until the tube is drawing 30 milliamperes.

Having once adjusted the tube to this condition, the operator should read and record the amperage in the filament circuit. To reproduce the condition he then needs merely to adjust the filament current to this same value and set his high tension transformer control on the same button. In this way, after his technique is once established, he never tests the tube by operating it, but is guided solely by the ammeter and the high tension transformer control button. While this method is generally applicable, it is not universally so, as it will be found that with certain types of generators the same control button and the same milliamperage as has been used with other tubes will not give the same penetration.

In other cases, the radiographer will be accustomed to adjust his tube by means of the milliammeter and the parallel gap. This procedure can be applied equally as well to the Coolidge Tube, and will naturally be the one first used in all cases where the operator is not familiar with his machine. Knowing that he wants, for example, 20 milliamperes and a 5-in. parallel gap, he will start with the filament control adjusted for the lowest possible current. He will then adjust the filament control and run up to higher buttons on the main control until the tube is drawing 20 milliamperes and backing up the 5-inch gap. As before he will then read and record the amperage in the

The matter of the thickness of the part and the time of exposure may best be determined by the judgment and experience of the operator. The figures given above are intended only as an illustration of the method and not as a guide for the making of radiographs.

Fig. 11 shows the radiator tube enclosed in the lead glass protective shield.

This shield is made of glass containing enough lead so that, for the same protective effect, it is but four times as thick as sheet lead. The walls of this shield are $\frac{1}{4}$ in. thick, giving X-ray protection equivalent to metallic lead $\frac{1}{16}$ in. thick.

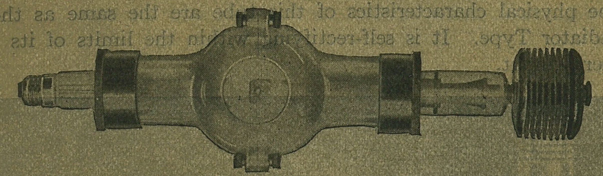

Fig. 11. RADIATOR TYPE COOLIDGE X-RAY TUBE ENCLOSED IN LEAD GLASS PROTECTIVE SHIELD

This shield is made in two halves which are identical and interchangeable. The joint is ground and is made at right angles to the long axis of the shield. It is evident that even if the joint does not fit tightly, no X-rays can escape unless the focal spot happens to be centered directly in line with the ground surfaces.

The outer ends of each half of the shield are threaded to take the screw caps. These caps force tapered split bushings of cork in between the arms of the X-ray tube and the shield. This holds the tube securely in position in the shield and prevents rotation.

The use of this shield is recommended in cases where adequate X-ray protection is not otherwise afforded.

METHOD OF OPERATION

When operating the Radiator Tube on machines delivering rectified current, the same general instructions apply as for the Universal Type Tube, taking care, however, that the energy limitation of the tube is never exceeded.

When operating this tube rectifying its own current, the change of conditions makes necessary certain changes in methods of operation.

THE SPARK GAP

Upon operating the tube directly from the secondary of a transformer, the "inverse" voltage is always higher than the "useful" voltage. Consequently, the measurement of tube voltage by a parallel spark gap used in the ordinary way, would, in general, be very misleading, as the observed spark length corresponds to the "inverse" voltage and not to that which produces the X-rays and hence determines their nature.

APPARATUS

Apparatus for operating this tube rectifying its own current is usually designed to furnish a voltage corresponding to a 5-in. gap between points. Experience has shown that if all radiographs are taken with the same voltage, the *average* quality and diagnostic value is better than if an attempt is made to vary the voltage.

The same has been shown to be true for variations of current through the tube. We, therefore, recommend that the Radiator Tube be operated always with the same voltage (back-up spark) and milliamperage. This should be the maximum capacity for which the tube is designed as indicated by the markings.

When operating a tube in this manner, it is also convenient to use always the same distance between focal spot and plate for most radiographs. This reduces the number of variable factors which influence the making of a radiograph to one, namely, the time of exposure. The operator having a machine and the tube once set to work at a fixed rate of, say, 5-in. back up and 10 milliamperes and a fixed focal-spot distance of 18 in., has his mind entirely free to devote to proper posing of the part to be radiographed. Once posed, he has only to decide the time of exposure necessary and close the switch for that length of time. For example, with the settings made as above, if the part to be radiographed is a hand or wrist, the operator has only to close the switch for 1 sec. For a medium sized knee, 5 sec., for a shoulder 10 sec. If the shoulder is thicker than medium size, 12 sec., or even 14 sec. might be necessary, and if thinner than medium size, 8 sec. will perhaps be sufficient.

filament circuit and the number of the control button and will be subsequently guided solely by this.

When excessively high energy inputs are employed, the tungsten at the focal spot melts and volatilizes. This results in a sudden lowering of the tube resistance which disappears instantly upon lowering the energy input, but the vaporized tungsten deposits in a thin film over the active hemisphere of the tube. (This mirror-like metal deposit on the inside of the glass should not be confused with the violet coloration which always results when the particular kind of glass used in these bulbs is

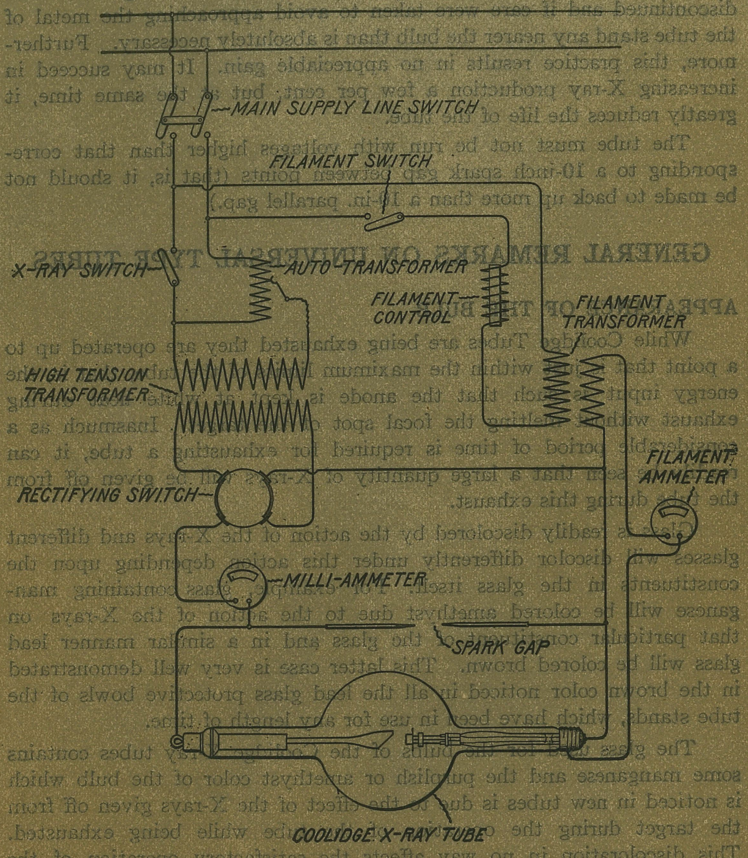

Fig. 6. WIRING DIAGRAM OF UNIVERSAL TYPE COOLIDGE X-RAY TUBE ON RECTIFIED CURRENT

subjected to prolonged exposure to X-rays. This violet color is due to some change taking place within the glass itself and is perfectly harmless.) The thin film of tungsten exerts no appreciable filtering effect upon the X-rays, but it does disturb the electrical conditions within the tube. Experiments have shown that a grounded metal wire may be brought up into actual contact with a clean bulb when the tube is operating, whereas with a tube having a metal deposit inside, such a wire must be moved away a number of inches to avoid puncturing the tube. The metal of the tube stand is usually grounded and the number of punctured bulbs would be greatly reduced if the practice of blackening bulbs were discontinued and if care were taken to avoid approaching the metal of the tube stand any nearer the bulb than is absolutely necessary. Furthermore, this practice results in no appreciable gain. It may succeed in increasing X-ray production a few per cent, but at the same time, it greatly reduces the life of the tube.

The tube must not be run with voltages higher than that corresponding to a 10-inch spark gap between points (that is, it should not be made to back up more than a 10-in. parallel gap.)

GENERAL REMARKS ON UNIVERSAL TYPE TUBES

APPEARANCE OF THE BULB

While Coolidge Tubes are being exhausted they are operated up to a point that is just within the maximum limits of the tube, that is, the energy input is such that the anode is kept at white heat during exhaust without melting the focal spot of the target. Inasmuch as a considerable period of time is required for exhausting a tube, it can readily be seen that a large quantity of X-rays will be given off from the tube during this exhaust.

Glass is readily discolored by the action of the X-rays and different glasses will discolor differently under this action depending upon the constituents in the glass itself. For example, glass containing manganese will be colored amethyst due to the action of the X-rays on that particular constituent of the glass and in a similar manner lead glass will be colored brown. This latter case is very well demonstrated in the brown color noticed in all the lead glass protective bowls of the tube stands, which have been in use for any length of time.

The glass used for the bulbs of the Coolidge X-ray tubes contains some manganese and the purplish or amethyst color of the bulb which is noticed in new tubes is due to the effect of the X-rays given off from the target during the operation of the tube while being exhausted. This discoloration in no way affects the satisfactory operation of the tube.

In addition, in this type of tube, the temperature of the focal spot may be raised to that of the cathode spiral and even brought to the fusing point, while the tube is operating on alternating current, without the tube allowing any appreciable "inverse" current to pass. This last fact is probably explained by the presence of gas in the copper-tungsten anode and to the effect of this gas in reducing the thermionic emission of electrons from the focal spot.

HIGH TENSION CIRCUIT

Although this tube is self-rectifying and may be operated directly across the terminals of a high tension transformer or induction coil without the interposition of auxiliary rectifying devices, it will operate equally well on types of apparatus which deliver rectified high tension current.

Whether operated on rectified or unrectified current, the use of the auto-transformer as a means of control is recommended.

Fig. 10 shows a wiring diagram of a Radiator Tube operated directly across the terminals of a high tension transformer and showing the auto-transformer method of control.

CAPACITY OF THE TUBE

The important limiting factor of allowable energy input for the Radiator Tube is the area of the focal spot. On account of the special construction of the anode of the Radiator Type Tube, the heat from the target is rapidly conducted to the outside of the tube and dissipated by the copper radiator. This design insures that operation is always started with a comparatively cool target. The combination of great heat capacity and the ability to quickly conduct and radiate heat from the target makes it possible to apply a greater amount of energy to a given focal area. than with the Universal Type Tube. For a given capacity the focal spot of this type of tube is much smaller than is possible with the Universal Type Tube.

The energy limitation of each Radiator Tube will be found marked on the tube and care should be taken that this limit is not exceeded, otherwise the tube will be damaged.

Where only milliamperage is marked it indicates that the tube may be operated at an energy corresponding to the marked current and the voltage corresponding to a 5-in. parallel spark between points.

Each Radiator Tube is designed to carry the amount of energy indicated by the markings, for a period of time sufficient for making diagnostic radiographs which require the longest exposure or to carry a fluoroscopic load of 5 milliamperes, at a voltage corresponding to a 5-in. spark gap.

The tube should never be operated in such a manner as to heat the body of the anode beyond a temperature corresponding to a dull red heat.

as a result of "inverse" current, as it was when the experiment was started with the target at a dull red heat.

METHOD OF HEATING THE CATHODE

The filament of this tube is heated in the same manner as that of the Universal Type Tube.

THEORY OF OPERATION

In the Radiator Type of tube, the passage of "inverse" current is avoided by a construction which removes heat from the focal spot so rapidly that, in normal use, it never reaches the temperature at which an appreciable thermionic emission of electrons can take place.

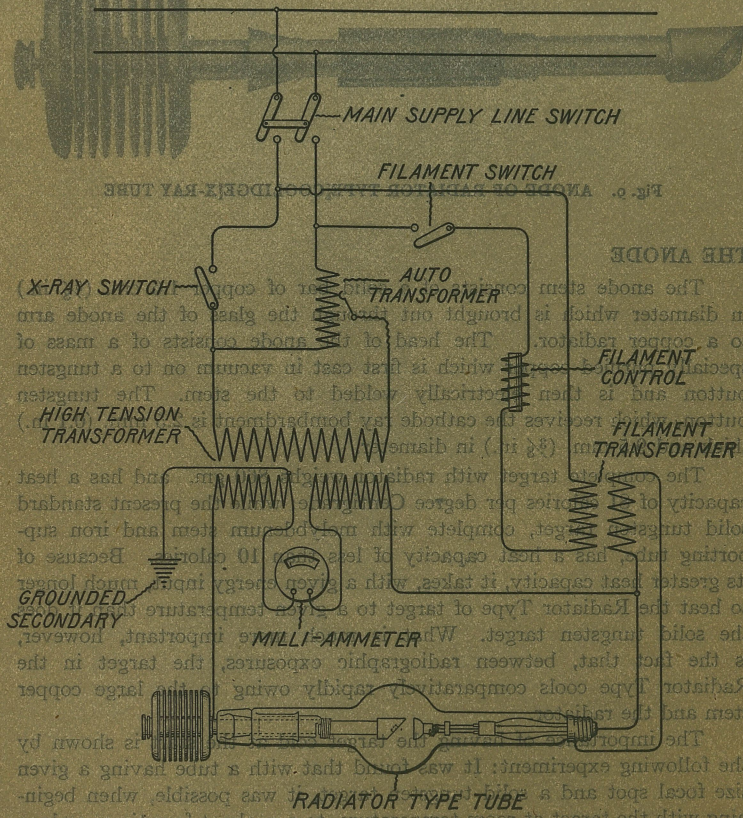

Fig. 10. WIRING DIAGRAM OF RADIATOR TYPE COOLIDGE X-RAY TUBE ON UNRECTIFIED CURRENT

APPEARANCE OF THE TARGET

There is generally a frosted area in the center of the target face of a new tube. This is due to a crystallization of the tungsten during the exhaust of the tube and the size of this area is not an indication of the size of the focal spot.

FLUORESCENT PHENOMENON

During the operation of some universal type tubes there will be noticed a clearly defined red band at the junction of the anode head and the molybdenum supporting rod. This red band is merely the fluorescent effect produced by the action of the reflected cathode rays upon the microscopic particles of abrasive material which are deposited in this junction during the process of grinding the anode.

RADIATOR TYPE COOLIDGE X-RAY TUBE

The radiator tube is designed solely for diagnostic purposes and is recommended for fluoroscopy and radiography only. It should never be used for therapy.

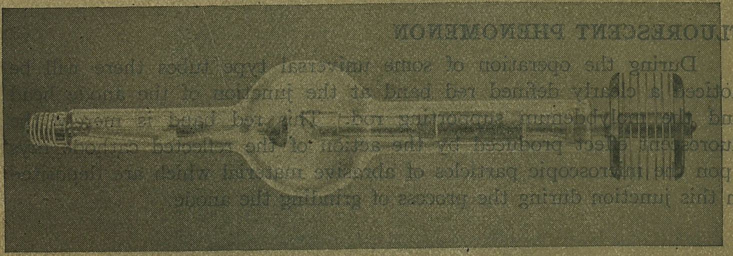

Fig. 7. RADIATOR TYPE COOLIDGE X-RAY TUBE

CHARACTERISTICS

The physical characteristics of this tube are in general the same as those of the Universal Type Tube. There is this important difference, however, that the Radiator Type Tube is capable of rectifying its own current. It may, therefore, be operated directly across the terminals of either an induction coil or a high tension transformer without the interposition of any auxiliary rectifying device. In construction, it is quite different from the Universal Type Tube.

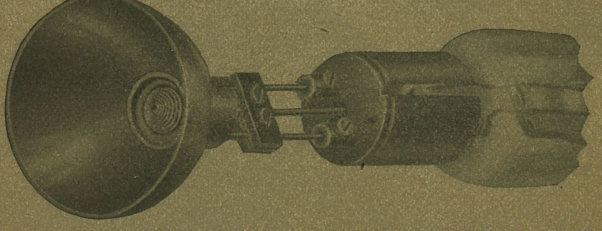

Fig. 8. CATHODE OF RADIATOR TYPE COOLIDGE X-RAY TUBE

DESCRIPTION OF RADIATOR TUBE

BULB

In the Radiator Type of Tube, by far the greatest part of the heat imparted to the target is conducted to the copper radiator, instead of being radiated through the glass wall of the bulb as is the case with the Universal Type Tube. It is, therefore, possible to make the glass bulb of the Radiator Type Tube quite small. The bulb measures 3¾ in. in diameter and the over-all length of the tube is approximately 19 in.

CATHODE

The filament, Fig. 8, which forms the cathode of this tube, is similar to that of the Universal Type Tube.

FOCUSING DEVICE

This consists of a cylindrical tube of molybdenum to which is attached a hemispherical cup of the same metal. By means of this construction a small focal spot with a very uniform distribution of energy is secured.

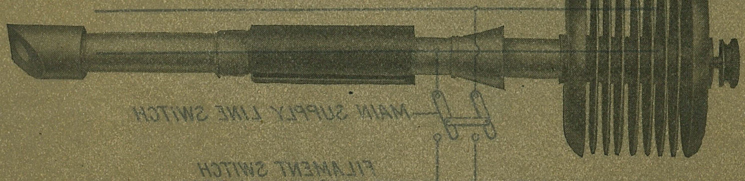

Fig. 9. ANODE OF RADIATOR TYPE COOLIDGE X-RAY TUBE

THE ANODE

The anode stem consists of a solid bar of copper 1.6 cm. (⅝ in.) in diameter which is brought out through the glass of the anode arm to a copper radiator. The head of the anode consists of a mass of specially purified copper which is first cast in vacuum on to a tungsten button and is then electrically welded to the stem. The tungsten button, which receives the cathode ray bombardment is 2.5 mm. (0.1 in.) thick and 9.5 mm. (⅜ in.) in diameter.

The complete target with radiator weighs 860 gm. and has a heat capacity of 81 calories per degree Centigrade, while the present standard solid tungsten target, complete with molybdenum stem and iron supporting tube, has a heat capacity of less than 10 calories. Because of its greater heat capacity, it takes, with a given energy input, much longer to heat the Radiator Type of target to a given temperature than it does the solid tungsten target. What is much more important, however, is the fact that, between radiographic exposures, the target in the Radiator Type cools comparatively rapidly owing to the large copper stem and the radiator.

The importance of having the target cold at the start is shown by the following experiment: It was found that with a tube having a given size focal spot and a solid tungsten target, it was possible, when beginning with the target at room temperature, to run about four times as long with the maximum, allowable energy input, before damaging the tube